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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	MI40-177	*Total Pages*	143

First Named Inventor or Application Identifier

Roy Greeff

Express Mail Label No.	EL169866319US

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents

ADDRESS TO. Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. [X] **Fee Transmittal Form** *(Submit an original, and a duplicate for fee processing)*

2. [X] **Specification** [*Total Pages* 48] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure

3. [X] **Drawing(s)** *(35 USC 113)* [*Total Sheets* 10]

4. **Oath or Declaration** [*Total Pages* 2]
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17 completed)* **[Note Box 5 below]**
      i. [ ] **DELETION OF INVENTOR(S)** Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

5. [ ] **Incorporation By Reference** *(useable if Box 4b is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. [ ] Microfiche Computer Program *(Appendix)*

7. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [X] Assignment Papers (cover sheet & document(s))

9. [X] 37 CFR 3 73(b) Statement *(when there is an assignee)* [X] Power of Attorney

10. [ ] English Translation Document *(if applicable)*

11. [X] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations

12. [ ] Preliminary Amendment

13. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*

14. [ ] Small Entity Statement(s) [ ] Statement filed in prior application, Status still proper and desired

15 [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. [X] Other: Check for $1,490.00

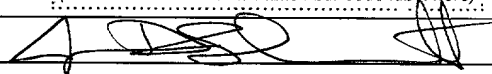**17. If a CONTINUING APPLICATION,** *check appropriate box and supply the requisite information·*
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18. CORRESPONDENCE ADDRESS

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APPLICATION FOR LETTERS PATENT

* * * * *

PHASE SHIFTERS, INTERROGATORS, METHODS OF
SHIFTING A PHASE ANGLE OF A SIGNAL, AND METHODS
OF OPERATING AN INTERROGATOR

* * * * *

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PHASE SHIFTERS, INTERROGATORS, METHODS OF SHIFTING A PHASE ANGLE OF A SIGNAL, AND METHODS OF OPERATING AN INTERROGATOR

TECHNICAL FIELD

The present invention relates to phase shifters, interrogators, methods of shifting a phase angle of a signal, and methods of operating an interrogator.

BACKGROUND OF THE INVENTION

Electronic identification devices, such as radio frequency identification devices (RFIDs), are known in the art. Such devices are typically used for inventory tracking. As large numbers of objects are moved in inventory, product manufacturing, and merchandising operations, there is a continuous challenge to accurately monitor the location and flow of objects. Additionally, there is a continuing goal to determine the location of objects in an inexpensive and streamlined manner. One way of tracking objects is with an electronic identification system.

One presently available electronic identification system utilizes a magnetic coupling system. In some cases, an identification device may be provided with a unique identification code in order to distinguish between a number of different devices. Typically, the devices are entirely passive (have no power supply), which results in a small and portable package. However, such identification systems are only capable of operation over a relatively short range, limited by the size of a magnetic field used to supply power to the devices and to communicate with the devices.

Another type of wireless electronic identification system is an active wireless electronic identification system. Attention is directed towards commonly assigned U.S. Patent Application Serial No. 08/705,043, filed August 29, 1996, and incorporated herein by reference, which describes such active systems in detail. One such system is sold by Micron Communications Inc., 3176 S. Denver Way, Boise, Idaho 83705 under the trademark Microstamp Engine (TM).

These systems include integrated circuit devices which include an active transponder and are intended to be affixed to an object to be monitored. The devices are capable of receiving and processing instructions transmitted by an interrogator. A device receives the instruction, if within range, then processes the instruction and transmits a response, if appropriate. The interrogation signal and the responsive signal are typically radio-frequency (RF) signals produced by an RF transmitter circuit.

Because active devices have their own power sources, they do not need to be in close proximity to an interrogator or reader to receive power via magnetic coupling. Therefore, active transponder devices tend to be more suitable for applications requiring tracking of a tagged device that may not be in close proximity to an interrogator. For example, active transponder devices tend to be more suitable for inventory control or tracking.

The active transponder is capable of using backscatter communication techniques in responding to an interrogator. The

interrogator outputs a polling signal followed by a continuous wave (CW) signal. The integrated circuit devices are configured to modulate the continuous wave signal in backscatter communication configurations. This modulation typically includes selective reflection of the continuous wave signal. The reflected continuous wave signal includes the reply message from the remote devices which is demodulated by the interrogator.

Certain drawbacks have been identified with the use of backscatter communication techniques. For example, the transmission of the continuous wave signal using the interrogator can desensitize the receiver of the interrogator during reception thereby of reply signals from associated remote devices. In particular, some of the continuous wave signal tends to bleed through to the received reply messages. Such results in degradation of wireless communications.

Systems have been provided which improve wireless communications without the drawbacks associated with conventional devices. Variable phase shifters can be used in such systems. However, conventional variable phase shifters are typically very expensive and typically only operate within a certain specified range, (e.g., 0 to 180 degrees).

SUMMARY OF THE INVENTION

The present invention includes variable phase shifters, interrogators, methods of shifting a phase angle of a signal, and methods of operating an interrogator.

It is desired to reduce power within a modulated return link continuous wave signal of a coherent backscatter communication system including an interrogator and at least one remote communication device. Exemplary remote communication devices include remote intelligent communication devices and radio frequency identification devices (RFID) of electronic identification systems.

An exemplary interrogator comprises a coherent interrogator configured to provide backscatter communications. More specifically, the interrogator is configured to output a forward link communication and a wireless continuous wave signal using a transmitter. The interrogator is also configured to output a local continuous wave signal to a receiver of the interrogator following transmission of the forward link communication. Provision of the local signal enables coherent operation of the interrogator. The interrogator is operable to receive return link communications from at least one remote communication device responsive to transmission of the forward link wireless communication.

The interrogator preferably includes a receiver operable to reduce the amplitude of a carrier signal of the return link communication. For backscatter communications, the remote communication device is configured to modulate the continuous wave signal providing a carrier component and side band components. The receiver of the interrogator is preferably configured to reduce the amplitude of the carrier component while maintaining the amplitudes of the side band components.

Variable phase shifters are disclosed to adjust the phase angle of the local continuous wave signal using a determined phase shift angle to reduce bleed through. The determined phase shift angle may be varied during operation of the interrogator. According to one aspect of the present invention, a phase shifter includes a power divider configured to provide plural quadrature components of an input signal, such as the local continuous wave signal. Plural mixers are provided to scale the quadrature components using the phase shift angle. A second power divider is provided to combine the scaled quadrature components to shift the phase angle of the input signal by the phase shift angle.

Methods of certain aspects of the present invention provide shifting of a phase angle of an input signal according to a phase shift angle. A method of one aspect includes providing the input signal into plural components. Thereafter, the components are scaled using the phase shift angle and combined to shift the phase angle of the input signal by the phase shift angle.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

Fig. 1 is a block diagram of an exemplary communication system.

Fig. 2 is a front view of a wireless remote communication device according to one embodiment.

Fig. 3 is a front view of an employee badge according to another embodiment.

Fig. 4 is a functional block diagram of an exemplary transponder included in the remote communication device of Fig. 2.

Fig. 5 is a functional block diagram of an exemplary interrogator of the communication system.

Fig. 6 is a functional block diagram of an RF section of the interrogator.

Fig. 7 is a functional block diagram of an adaptive canceler of the RF section.

Fig. 8 is a schematic diagram of amplitude detectors and an amplitude adjuster according to one adaptive canceler configuration.

Fig. 9 is a graphical illustration of a summed return link communication outputted from the adaptive canceler.

Fig. 10 is a schematic diagram illustrating one configuration of an amplitude detector and a phase adjuster of the adaptive canceler.

Fig. 11 is a graphical illustration of a received return link communication.

Fig. 12 is a graphical illustration of a summed return link communication.

Fig. 13 is a diagrammatic representation of a forward link communication and a return link communication within the communication system.

Fig. 14 is a circuit schematic showing a variable phase shifter used in the adaptive canceler, in one embodiment, and which also has other uses.

Fig. 15 is a graphical illustration of a relationship between I and Q components in the variable phase shifter of Fig. 14.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

Fig. 1 illustrates a wireless communication system 10 embodying the invention. Communication system 10 comprises an electronic identification system in the embodiment described herein. Further, the described communication system 10 is configured for backscatter communications as described in detail below. Other communication protocols are utilized in other embodiments.

The depicted communication system 10 includes at least one electronic wireless remote communication device 12 and an interrogator 26. Radio frequency communications can occur intermediate remote communication devices 12 and interrogator 26 for use in identification systems and product monitoring systems as exemplary applications.

Devices 12 include radio frequency identification devices (RFID) or remote intelligent communication (RIC) devices in the embodiments

described herein. Exemplary devices 12 are disclosed in U.S. Patent Application Serial No. 08/705,043, filed August 29, 1996. Plural wireless remote communication devices 12 typically communicate with interrogator 26 although only one such device 12 is illustrated in Fig. 1.

In one embodiment, wireless remote communication device 12 comprises a wireless identification device such as the MicroStamp (TM) integrated circuit available from Micron Communications, Inc., 3176 S. Denver Way, Boise, Idaho 83705. Such a remote communication device 12 can be referred to as a tag or card as illustrated and described below.

Although multiple communication devices 12 can be employed in communication system 10, there is typically no communication between multiple devices 12. Instead, the multiple communication devices 12 communicate with interrogator 26. Multiple communication devices 12 can be used in the same field of interrogator 26 (i.e., within the communications range of interrogator 26). Similarly, multiple interrogators 26 can be in proximity to one or more of devices 12.

The above described system 10 is advantageous over prior art devices that utilize magnetic field effect systems because, with system 10, a greater range can be achieved, and more information can be obtained (instead of just identification information). As a result, such a system 10 can be used, for example, to monitor large warehouse inventories having many unique products needing individual discrimination

to determine the presence of particular items within a large lot of tagged products.

Remote communication device 12 is configured to interface with interrogator 26 using a wireless medium in one embodiment. More specifically, communications intermediate communication device 12 and interrogator 26 occur via an electromagnetic link, such as an RF link (e.g., at microwave frequencies) in the described embodiment. Interrogator 26 is configured to output forward link wireless communications 27. Further, interrogator 26 is operable to receive reply or return link wireless communications 29 from devices 12 responsive to the outputting of forward link communication 27. In accordance with the above, forward link communications and return link communications comprise wireless signals, such as radio frequency signals, in the described embodiment. Other forms of electromagnetic communication, such as infrared, acoustic, etc. are possible.

Interrogator unit 26 includes a plurality of antennas X1, R1, as well as transmitting and receiving circuitry, similar to that implemented in devices 12. Antenna X1 comprises a transmit antenna and antenna R1 comprises a receive antenna individually connected to interrogator 26.

In operation, interrogator 26 transmits the interrogation command or forward link communication signal 27 via antenna X1. Communication device 12 is operable to receive the incoming forward link signal. Upon receiving signal 27, communication device 12 is

operable to respond by communicating the responsive reply or return link communication signal 29. Communications of system 10 are described in greater detail below.

In one embodiment, responsive signal 29 is encoded with information that uniquely identifies, or labels the particular device 12 that is transmitting, so as to identify any object, animal, or person with which communication device 12 is associated.

More specifically, remote device 12 is configured to output an identification signal within reply link communication 29 responsive to receiving forward link wireless communication 27. Interrogator 26 is configured to receive and recognize the identification signal within the return or reply link communication 29. The identification signal can be utilized to identify the particular transmitting communication device 12.

Referring to Fig. 2, one embodiment of remote communication device 12 is illustrated. The depicted communication device 12 includes a transponder 16 having a receiver and a transmitter as described below. Communication device 12 further includes a power source 18 connected to transponder 16 to supply operational power to transponder 16. In the illustrated embodiment, transponder 16 is in the form of an integrated circuit 19. However, in alternative embodiments, all of the circuitry of transponder 16 is not necessarily all included in integrated circuit 19.

Power source 18 is a thin film battery in the illustrated embodiment, however, in alternative embodiments, other forms of power

sources can be employed. If the power source 18 is a battery, the battery can take any suitable form. Preferably, the battery type will be selected depending on weight, size, and life requirements for a particular application. In one embodiment, battery 18 is a thin profile button-type cell forming a small, thin energy cell more commonly utilized in watches and small electronic devices requiring a thin profile. A conventional button-type cell has a pair of electrodes, an anode formed by one face and a cathode formed by an opposite face. In an alternative embodiment, the battery comprises a series connected pair of button type cells.

Communication device 12 further includes at least one antenna connected to transponder 16 for wireless transmission and reception. In the illustrated embodiment, communication device 12 includes at least one receive antenna 44 connected to transponder 16 for radio frequency reception by transponder 16, and at least one transmit antenna 46 connected to transponder 16 for radio frequency transmission by transponder 16. The described receive antenna 44 comprises a loop antenna and the transmit antenna 46 comprises a dipole antenna.

Communication device 12 can be included in any appropriate housing or packaging. Fig. 2 shows but one example of a housing in the form of a miniature housing 11 encasing device 12 to define a tag which can be supported by an object (e.g., hung from an object, affixed to an object, etc.).

Referring to Fig. 3, an alternative housing is illustrated. Fig. 3 shows a housing in the form of a card 13. Card 13 preferably comprises plastic or other suitable material. Plastic card 13 houses communication device 12 to define an employee identification badge including the communication device 12. In one embodiment, the front face of card 13 has visual identification features such as an employee photograph or a fingerprint in addition to identifying text.

Although two particular types of housings have been disclosed, the communication device 12 can be included in any appropriate housing. Communication device 12 is preferably of a small size that lends itself to applications employing small housings, such as cards, miniature tags, etc. Larger housings can also be employed. The communication device 12, provided in any appropriate housing, can be supported from or attached to an object in any desired manner.

Fig. 4 is a high level circuit schematic of transponder 16 utilized in the devices of Figs. 1-3. In the embodiment shown in Fig. 4, transponder 16 is implemented within monolithic integrated circuit 19. In the illustrated embodiment, integrated circuit 19 comprises a single die, having a size of 209 x 116 mils^2, including a receiver 30, transmitter 32, microcontroller or microprocessor 34, a wake up timer and logic circuit 36, a clock recovery and data recovery circuit 38, and a bias voltage and current generator 42. Integrated circuit 19 preferably comprises a small outline integrated circuit (SOIC) package.

Receiver 30 and transmitter 32 comprise wireless communication circuitry configured to communicate wireless signals.

In one embodiment, communication devices 12 switch between a "sleep" mode of operation, and higher power modes to conserve energy and extend battery life during periods of time where no interrogation signal 27 is received by devices 12, using the wake up timer and logic circuitry 36.

In one embodiment, a spread spectrum processing circuit 40 is included in transponder 16. In this embodiment, signals transmitted and received by interrogator 26 and signals transmitted and received by communication device 12 are modulated spread spectrum signals. Many modulation techniques minimize required transmission bandwidth. However, the spread spectrum modulation techniques employed in the illustrated embodiment require a transmission bandwidth that is up to several orders of magnitude greater than the minimum required signal bandwidth. Although spread spectrum modulation techniques are bandwidth inefficient in single user applications, they are advantageous where there are multiple users, as is the case with the preferred radio frequency identification communication system 10 of the present invention.

The spread spectrum modulation technique of the illustrated embodiment is advantageous because the interrogator signal can be distinguished from other signals (e.g., radar, microwave ovens, etc.) operating at the same frequency. The spread spectrum signals

transmitted by communication device 12 and interrogator 26 are pseudo random and have noise-like properties when compared with the digital command or reply. The illustrated embodiment employs direct sequence spread spectrum (DSSS) modulation.

In operation, interrogator 26 sends out a command that is spread around a certain center frequency (e.g, 2.44 GHz). After the interrogator transmits the command, and is expecting a response, the interrogator switches to a continuous wave (CW) mode for backscatter communications. In the continuous wave mode, interrogator 26 does not transmit any information. Instead, the interrogator just transmits a radio frequency continuous wave signal. In the described embodiment, the continuous wave signal comprises a radio frequency 2.44 GHz carrier signal. In other words, the continuous wave signal transmitted by interrogator 26 is not modulated. After communication device 12 receives the forward link communication from interrogator 26, communication device 12 processes the command.

If communication device 12 is operating in a backscatter mode, device 12 modulates the continuous wave signal providing a modulated continuous wave signal to communicate return link communication 29 responsive to reception of forward communication signal 27. Communication device 12 may modulate the continuous wave signal according to a subcarrier or modulation signal. Modulation by device 12 comprises selective reflection of the continuous wave signal. In particular, device 12 alternately reflects or does not reflect the

continuous wave signal from the interrogator to send its reply. For example, in the illustrated embodiment, two halves of a dipole antenna are either shorted together or isolated from each other to send a reply. Alternatively, communication device 12 can communicate in an active mode.

The modulated continuous wave signal communicated from device 12 comprises a carrier component and plural side band components about the carrier component resulting from the modulation. More specifically, the modulated continuous wave signal output from device 12 includes a radio frequency continuous wave signal having a first frequency (2.44 GHz), also referred to as a carrier component, and a subcarrier modulation signal having a different frequency (e.g., 600 kHz) and which provides the side band components. In particular, the side band components are at +/- 600 kHz of the carrier component. The carrier and side band components are illustrated in Fig. 11 and Fig. 12.

In one embodiment, the clock for transponder 16 is extracted from the incoming message itself by clock recovery and data recovery circuitry 38. This clock is recovered from the incoming message, and used for timing for microcontroller 34 and all the other clock circuitry on the chip, and also for deriving the transmitter carrier or the subcarrier, depending on whether the transmitter is operating in active mode or backscatter mode.

In addition to recovering a clock, the clock recovery and data recovery circuit 38 also performs data recovery on valid incoming signals. The valid spread spectrum incoming signal is passed through the spread spectrum processing circuit 40, and the spread spectrum processing circuit 40 extracts the actual ones and zeros of data from the incoming signal. More particularly, the spread spectrum processing circuit 40 takes chips from the spread spectrum signal, and reduces individual thirty-one chip sections down to a bit of one or zero, which is passed to microcontroller 34.

Microcontroller 34 includes a serial processor, or I/O facility that receives the bits from spread spectrum processing circuit 40. The microcontroller 34 performs further error correction. More particularly, a modified hamming code is employed, where each eight bits of data is accompanied by five check bits used by the microcontroller 34 for error correction. Microcontroller 34 further includes a memory, and after performing the data correction, microcontroller 34 stores bytes of the data bits in memory. These bytes contain a command sent by the interrogator 26. Microcontroller 34 is configured to respond to the command.

For example, interrogator 26 may send a command requesting that any communication device 12 in the field respond with the device's identification number. Status information can also be returned to interrogator 26 from communication devices 12.

Communications from interrogator 26 (i.e., forward link communications) and devices 12 (i.e., return link communications) have a similar format. Exemplary communications are discussed below with reference to Fig. 13. More particularly, the forward and reply communications individually include a calibration period, preamble, and Barker or start code which are followed by actual data in the described embodiment. The incoming forward link message and outgoing reply preferably also include a check sum or redundancy code so that transponder 16 or interrogator 26 can confirm receipt of the entire message or reply.

Communication devices 12 typically include an identification sequence identifying the particular tag or device 12 sending the reply. Such implements the identification operations of communication system 10.

After sending a command, interrogator 26 sends the unmodulated continuous wave signal. Return link data can be Differential Phase Shift Key (DPSK) modulated onto the continuous wave signal using a square wave subcarrier with a frequency of approximately 600 kHz (e.g., 596.1 kHz in one embodiment). A data 0 corresponds to one phase and data 1 corresponds to another, shifted 180 degrees from the first phase.

The subcarrier or modulation signal is used to modulate antenna impedance of transponder 16 and generate the modulated continuous wave signal. For a simple dipole, a switch between the two halves of

the dipole antenna is opened and closed. When the switch is closed, the antenna becomes the electrical equivalent of a single half-wavelength antenna that reflects a portion of the power being transmitted by the interrogator. When the switch is open, the antenna becomes the electrical equivalent of two quarter-wavelength antennas that reflect very little of the power transmitted by the interrogator. In one embodiment, the dipole antenna is a printed microstrip half wavelength dipole antenna.

Referring to Fig. 5, one embodiment of interrogator 26 is illustrated. The depicted interrogator 26 includes a microcontroller 70, a field programmable gate array (FPGA) 72, and RF section 74. In the depicted embodiment, microcontroller 70 comprises a MC68340 microcontroller available from Motorola, Inc. FPGA 72 comprises an XC4028 device available from Xilinx, Inc. Further details of components 70, 72, and 74 are described below.

RAM 76, EPROM 78 and flash memory 80 are coupled with microcontroller 70 in the depicted embodiment. Microcontroller 70 is configured to access an applications program for controlling the interrogator 26 and interpreting responses from devices 12. The processor of microcontroller 70 is configured to control communication operations with remote communication devices 12 during normal modes of operation. The applications program can also include a library of radio frequency identification device applications or functions. These

functions effect radio frequency communications between interrogator 26 and communication device 12.

RF section 74 is configured to handle wireless (e.g., radio frequency) communications with remote communication devices 12. DPSK modulation techniques can be utilized for communications intermediate devices 12 and interrogator 26. RF section 74 can include downconversion circuitry for generating in-phase (I) and quadrature (Q) signals which contain the DPSK modulated subcarrier for application to FPGA 72 during return link communications.

Plural antennas, including a transmit antenna X1 and a receive antenna R1 are coupled with RF section 74 for wireless RF communications. Plural RF transmit (TX) ports and RF receive (RX) ports (not shown) are coupled with RF section 74 in a preferred embodiment. Provision of plural TX ports and RX ports enables interrogator 26 to minimize the effects of multipath when communicating with plural remote communication devices 12.

Analog to digital converters 82, 84 provide received analog RF signals into a digital format for application to FPGA 72. In particular, analog to digital converters 82, 84 are implemented intermediate FPGA 72 and RF section 74 for both in-phase (I) and quadrature (Q) communication lines. An additional connection 85 is provided intermediate FPGA 72 and RF section 74. Digital signals output from FPGA 72 via connection 85 are converted to RF signals by RF section 74. Connection 85 can be utilized to transmit phase lock

loop (PLL) information, antenna diversity selection information and other necessary communication information. During forward link communications, FPGA 72 is configured to format communication packets received from microcontroller 70 into a proper format for application to RF section 74 for communication.

FPGA 72 is configured to demodulate return link communications received from remote communication devices 12 via RF section 74. FPGA 72 is configured in the described embodiment to perform I and Q combination operations during receive operations. The described FPGA 74 further includes delay and multiplication circuitry to remove the subcarrier. FPGA 74 can also include bit synchronization circuitry and lock detection circuitry. Data, clock and lock detection signals generated within FPGA 74 are applied to microcontroller 70 for processing in the described embodiment.

Microcontroller 70 is configured to control operations of interrogator 26 including outputting of forward link communications and receiving reply link communications. EPROM 78 is configured to store original code and settings selected for the particular application of communication system 10. Flash memory 80 is configured to receive software code updates which may be forwarded to interrogator 26.

RAM device 76 is configured to store data during operations of communication system 10. Such data can include information regarding communications with associated remote communication devices 12 and status information of interrogator 26 during normal modes of operation.

Referring to Fig. 6, an exemplary embodiment of RF circuitry 74 is illustrated. The depicted RF circuitry 74 includes a transmit path 86 and a receive path 87. In the depicted embodiment, RF section 74 includes a transmitter 90, coupler 91 and power amplifier 92 within transmit data path 86. Receive path 87 includes a receiver 95 comprising processing circuitry 96 and an adaptive canceler 97 in the depicted embodiment.

Communication paths 86, 87 are coupled with respective antennas X1, R1. Transmit path 86 is additionally coupled with FPGA 72 via connection 85. Receive path 87 is coupled with analog-to-digital converters 82, 84 via the I, and Q connection lines.

During communication operations, transmitter 90 is configured to output a radio frequency wireless forward link communication 27 and a radio frequency wireless continuous wave signal using coupler 91 and antenna X1. Further, transmitter 90 is also configured to output a local continuous wave signal using coupler 91. Transmitter 90 is preferably configured to simultaneously output the wireless continuous wave signal using antenna X1, and the local continuous wave signal using coupler 91. The wireless continuous wave signal transmitted via antenna X1 and the local continuous wave signal provided to receiver 95 via coupler 91 have a common frequency (e.g., 2.44 GHz in the described embodiment).

Receiver 95 is operable to receive the return link communications 29 from at least one remote communication device 12

using antenna R1. As described in detail below, adaptive canceler 97 of receiver 95 is configured to receive the local continuous wave signal from coupler 91. Provision of the local signal provides a coherent backscatter interrogator 26 including a coherent transmitter 90 and receiver 95.

As previously described, return link communication 29 comprises a modulated radio frequency continuous wave signal in the described embodiment. The modulated signal comprises a carrier signal located at the frequency of the wireless continuous wave signal (e.g., 2.44 GHz), and side bands located at +/- 600 kHz about the frequency of the carrier signal. In the described embodiment, receiver 95 is configured to reduce the power or amplitude of the return link communication. More specifically, receiver 95 is configured to reduce the power or amplitude of the carrier signal of the return link communication.

In one embodiment, receiver 95 is operable to reduce the amplitude of the return link communication comprising the modulated continuous wave signal using the local continuous wave signal. More specifically, receiver 95 is configured to reduce the amplitude of the return link communications received by antenna R1 at the common frequency of the continuous wave signals in the described embodiment.

As described in detail below, receiver 95 is configured to receive the local continuous wave signal from coupler 91 and adjust the amplitude and phase of the local continuous wave signal. Such adjustment provides an adjusted continuous wave signal. In particular,

the amplitude of the local continuous wave signal is adjusted responsive to the amplitude of the modulated continuous wave signal. Preferably, the amplitude of the local continuous wave signal is adjusted to match the amplitude of the received return link communication. The amplitude of the local continuous wave signal is adjusted before adjustment of the phase of the local continuous wave signal in the described embodiment. Following amplitude and phase adjustment, receiver 95 is configured to sum the adjusted continuous wave signal with the modulated continuous wave signal. Thereafter, the summed return link communication having a reduced amplitude at the frequency of the wireless continuous wave signal is applied to processing circuitry 96.

Referring to Fig. 7, one embodiment of adaptive canceler 97 is illustrated. Adaptive canceler 97 is configured to reduce the amplitude of return link communications 29. More specifically, during backscatter communications, receive path 87 is susceptible to bleed through of the wireless continuous wave signal transmitted via antenna X1. More specifically, the wireless continuous wave signal communicated via transmit antenna X1 can saturate the front end of receiver 95. This leakage can desensitize receiver 95 and reduce the quality of wireless communications of interrogator 26 with remote communication devices 12.

Adaptive canceler 97 utilizes the local continuous wave signal received from transmitter 90 and coupler 91 to reduce the amplitude

of the return link communication received by antenna R1 at the frequency of the wireless continuous wave signal transmitted via antenna X1.

As previously described, transmitter 90 is configured to output local and wireless continuous wave signals using coupler 91. Initially, the local continuous wave signal is applied to a variable attenuator 105 within adaptive canceler 97. In the described embodiment, variable attenuator 105 comprises a voltage controlled attenuator. Variable attenuator 105 is configured to adjust the amplitude of the local continuous wave signal responsive to an external control signal discussed below.

Variable attenuator 105 outputs an amplitude adjusted local continuous wave signal. The amplitude adjusted local continuous wave signal is applied to a phase shifter 106. Phase shifter 106 preferably comprises a 360° phase shifter configured to provide an appropriate phase shift of the amplitude adjusted local continuous wave signal. Phase shifter 106 outputs an amplitude and phase adjusted local continuous wave signal which is also referred to as the adjusted continuous wave signal. Phase shifter 106 is controllable via an external control signal described below.

The amplitude and phase adjusted local continuous wave signal output from phase shifter 106 is supplied to a power divider 107. Power divider 107 operates to apply the signal to a detector 108 and coupler 109. Detector 108 is operable to measure the amplitude of the

adjusted local signal and apply an output signal to an amplitude adjuster 110.

Return link communication 29 received via antenna R1 is applied to a coupler 114. Coupler 114 applies the received return link communication 29 to coupler 109 and an amplitude detector 115. Detector 115 is configured to measure the amplitude of the received return link communication 29.

Referring to Fig. 8, exemplary embodiments of amplitude adjuster 110 and detectors 108, 115 are illustrated. Detectors 108, 115 individually comprise discrete components including diodes, resistors and capacitors. Detectors 108, 115 are configured to measure the amplitude of the respective adjusted continuous wave signal and the modulated continuous wave signal.

The measured amplitude values are applied to amplitude adjuster 110 which comprises a feedback amplifier configuration in the depicted embodiment. The illustrated analog implementation of amplitude adjuster 110 is configured to drive variable attenuator 105 to equalize the amplitudes of the adjusted continuous wave signal and the modulated continuous wave signal. Amplitude adjuster 110 is configured to compare the amplitudes of the adjusted continuous wave signal and the received return link communication comprising the modulated continuous wave signal. Thereafter, amplitude adjuster 110 is operable to output a control signal to variable attenuator 105 to match the

amplitudes of the respective signals. Other configurations of amplitude adjuster 110 are possible.

Referring again to Fig. 7, coupler 109 is configured to sum the adjusted continuous wave signal and the received modulated continuous wave signal to reduce the amplitude of the modulated continuous wave signal. The summed continuous wave signal or return link communication is applied to a coupler 118. Coupler 118 is configured to apply the summed signal to low noise amplifier (LNA) 119 and amplitude detector 120. Amplitude detector 120 is configured to measure the amplitude of the summed signal and apply an output signal to a phase adjuster 121.

Phase adjuster 121 is controllable responsive to amplitude adjuster 110. Once amplitude adjuster 110 and variable attenuator 105 have matched the amplitudes of the adjusted continuous wave signal and the received return link communication, amplitude adjuster indicates the match to phase adjuster 121 via a connection 122. Thereafter, phase adjuster 121 operates to select an appropriate phase shift of the amplitude adjusted local continuous wave signal.

In the described embodiment, phase adjuster 121 is configured to search across 360° of possible phase adjustments to detect a phase adjustment of the local continuous wave signal which provides maximum reduction of amplitude of the received modulated continuous wave signal at the continuous wave signal frequency. In particular, adaptive canceler 97 adjusts the phase of the local continuous wave signal

following matching of amplitudes of the local continuous wave signal and the received modulated continuous wave signal as indicated via connection 122.

Referring to Fig. 9, a graphical illustration of the amplitude of the summed return link communication, represented by reference numeral 136, is illustrated with respect to corresponding plural phase adjustments of the local continuous wave signal. In the depicted illustration, it is shown that a local minimum value 130 corresponds to approximately 150°. For such a situation following searching of 360°, phase adjuster 121 will apply an appropriate control signal to phase shifter 106 to implement the desired phase shift of approximately 150° to minimize the amplitude of the bleed through of the wireless continuous wave signal within the received return link communication.

Referring again to Fig. 7, the summed return link communication is applied to low noise amplifier 119 and processing circuitry 96. Phase adjuster 121 is operable to continuously monitor the amplitude of the summed return link communication and provide appropriate adjustments using control signals applied to phase shifter 106 to minimize the amplitude of the continuous wave signal within the summed return link communication applied to LNA 119.

Referring to Fig. 10, exemplary embodiments of amplitude detector 120 and phase adjuster 121 are illustrated. Amplitude detector 120 includes discrete components comprising a diode, resistor and capacitor.

Phase adjuster 121 comprises an analog-to-digital converter 124, processor 125 and digital-to-analog converter 126. Processor 125 can be configured to execute appropriate algorithms to implement sequential phase shifts of the local signal from 0° to 360°. The incremental step sizes can be adjusted. Therefore, processor 125 can compare the amplitudes of the summed return link communication signal responsive to various phase adjustments implemented by phase shifter 106. Following selection of an appropriate phase shift, phase adjuster 121 can continue to monitor the amplitude of the summed return link communication and update the phase shift as necessary to maintain maximum reduction of the continuous wave signal within the return link communication during communications. The depicted configurations of detector 120 and phase adjuster 121 are illustrative and other configurations can be utilized.

Referring to Fig. 11 and Fig. 12, the received return link communication applied to adaptive canceler 97 and the summed return link communication output from adaptive canceler 97 are illustrated. The received return link communication comprising the modulated continuous wave signal is illustrated as signal 132 in Fig. 11. The summed return link communication is represented by signal 136 of Fig. 12.

Signal 132 comprises a carrier component 133 and side band components 134. In the described embodiment, carrier 133 is centered at a frequency of 2.44 GHz and subcarrier side band components 134

are depicted at locations +/- 600 kHz of the carrier component 133. Signal 136 similarly comprises a carrier component 137 and side band components 138. Signal 136 includes carrier component 137 at a frequency of 2.44 GHz and side band components 138 at locations +/- 600 kHz of the carrier component 137.

As illustrated, the output summed return link communication signal 136 has a carrier component 137 having a reduced amplitude compared with the carrier component 133 of the received return link communication signal 132. Preferably, the amplitude of side band components 138 of summed return link communication signal 136 are maintained during the reduction of amplitude of the carrier component 137 as illustrated in Fig. 11 and Fig. 12.

In the depicted illustrations of Fig. 11 and Fig. 12, carrier component 137 of signal 136 is approximately 20 dBm less than carrier component 133 of received return link communication 132. Such indicates the reduction of amplitude of the return link communication signal at the frequency of the wireless continuous wave signal (e.g., 2.44 GHz) utilizing adaptive canceler 97.

Referring to Fig. 13, a diagrammatic illustration of forward link communication 27 and return link communication 29 is shown. Initially, forward link communication 27 is communicated using transmit antenna X1 of interrogator 26. Following an intermediate delay or guard band, return link communication 29 corresponding to remote communication device 12 is communicated.

Individual return link communications 29 include a calibration period 140 followed by a preamble 141 and actual data 142. Matching of amplitudes of the local continuous wave signal and the received return link communication and cycling through phases from 0 to 360° utilizing phase adjuster 121 and phase shifter 106 preferably occurs during calibration period 140. The minimum level 130 within the summed return link communication signal is preferably determined during calibration period 140.

Preamble 141 can be utilized to synchronize the processing circuitry 96 of receiver 95 with the actual return link communication 29 being received. Thereafter, data 142 communicated from remote communication device 12 is received. Adaptive canceler 97 is configured to make adjustments as necessary to the amplitude and phase of the local continuous signal during preamble period 141 and data period 142 to maintain maximum reduction of the continuous wave signal within the received return link communication 29.

Fig. 14 illustrates a variable phase shifter 106 in accordance with one embodiment of the invention. Conventional phase shifters available in the marketplace could be employed; however, these are extremely expensive. The phase shifter 106 illustrated in Fig. 14 is an inexpensive alternative. Additionally, the phase shifter 106 provides phase shifts of anywhere from 0 to 360 degrees.

The depicted phase shifter 106 uses a commonly available part known as an IQ upconverter or IQ downconverter 201. The IQ

upconverter or IQ downconverter 201 includes a first power divider 200 defining an input 210 and having two outputs 212 and 214, a second power divider 208 defining an output 202 and having two inputs 204, 206, and two mixers 216 and 218.

The mixer 216 is coupled between the output 212 of the first power divider 208 and the input 204 of the second power divider 200. The mixer 218 is coupled between the output 214 of the first power divider 208 and the input 206 of the second power divider 200.

In the described arrangement, first power divider 200 comprises a ninety degree power divider and second power divider 208 comprises a zero degree power divider. Power divider 200 receives an input signal having a phase angle from input 210 which is the amplitude adjusted local continuous wave signal received from variable attenuator 105 previously described.

Power divider 200 provides a ninety degree phase shift to the input signal to provide a first component and a second component in accordance with one embodiment of the invention. Inasmuch as power divider 200 provides a ninety degree phase shift, first and second components of the received signal may be referred to as quadrature components. In particular, the first component from output 212 is indicated as a cosine component $(Cos(\varpi t))$ and the second component from output 214 is indicated as a sine component $(Sin(\varpi t))$. The signal components $Cos(\varpi t)$ and $Sin(\varpi t)$ have a sine/cosine relationship as they are shifted ninety degrees from each other. The quadrature signal

components shifted ninety degrees apart are applied to respective mixers 216, 218.

The depicted phase shifter 106 further includes plural digital-to-analog (D/A) converters 224, 226, I, Q drivers 220, 222, and storage device 228. Phase adjuster 121 is coupled with storage device 228. A second input 203 of phase shifter 106 is provided intermediate phase adjuster 121 and storage device 228.

As previously described, phase adjuster 121 is configured to calculate a desired phase shift angle (also referred to herein as Φ) and apply the phase shift angle to storage device 228. More specifically, phase shifter 106 is configured to adjust the phase of the amplitude adjusted local continuous wave signal received from variable attenuator 105 responsive to control signals from phase adjuster 121 and corresponding to the phase shift angle. Appropriate control signals are generated within phase adjuster 121 to indicate the desired phase shift angle for shifting of the phase of the amplitude adjusted local continuous wave signal. In particular, the control signals correspond to the desired phase shift adjustment to provide the local minimum value 130 within the summed return link communication signal as previously described. The control signals identifying the proper phase adjustment are applied to phase shifter 106.

Storage device 228 comprises a look-up table in an exemplary embodiment. Such a look-up table may be implemented within an EPROM in one embodiment. Storage device 228 can have one

degree resolution, or other resolutions if desired. Storage device 228 is configured to store a plurality of sine values and cosine values, also referred to as I and Q digital values. Further, storage device 228 is configured to output one of the stored cosine values and one of the stored sine values to the respective D/A converters 224, 226 responsive to and corresponding to the received phase shift angle determined by phase adjuster 121. For example, if a 45 degree phase shift is desired as indicated from phase adjuster 121, storage device 228 outputs digital look-up table values of 0.707, 0.707 (i.e., cosine and sine of 45 degrees) which are provided to D/A converters 224, 226.

Storage device 228 is coupled with D/A converters 224, 226 which in turn are coupled with respective I and Q drivers 220, 222. The cosine and sine digital values outputted from storage device 228 are converted to analog voltages within D/A converters 224, 226. The corresponding analog voltage signals from D/A converters 224, 226 are applied to respective I and Q drivers 220, 222 to implement the proper phase shift within the outputted signal to minimize bleed through.

I driver 220 is coupled to mixer 216 and Q driver 222 is coupled to mixer 218 as illustrated. Mixers 216, 218 are configured to scale the respective cosine and sine components of the input signal $\cos(\varpi t)$, $\sin(\varpi t)$ using the phase shift angle of phase adjuster 121. In the described configuration, mixers 216, 218 individually act as multipliers and multiply the cosine and sine components of the input signal by the respective cosine and sine values from storage device 228 as provided

to I and Q drivers 220, 222. More specifically, mixers 216, 218 multiply the cosine and sine components $\cos(\varpi t)$, $\sin(\varpi t)$ of the input signal by voltages outputted by the respective I driver 220 and the Q driver 222 and corresponding to the cosine value and sine value outputted from storage device 228.

By adjusting the values outputted by the I driver 220 and the Q driver 222, a phase shift of anywhere between 0 degrees and 360 degrees can be obtained. Exemplary phase adjustments are described hereafter. Because the input signal components $\cos(\varpi t)$ and $\sin(\varpi t)$ are ninety degrees out of phase, if combined at the second power divider 200 comprising a zero degree power divider without use of multipliers 216, 218, the summed components represented as vectors would have the same value as the input signal plus a ninety degree phase shift of the input signal.

Assume, for example, that the input signal has a constant phase and an amplitude of 1. If the output signal is desired to have the exact same phase, then the I driver 220 is set to provide one volt to the mixer 216 and the Q driver 222 is set to provide zero volts to the mixer 218. Thus, the signal applied to output 202 would be the same as the signal received from input 210.

If a ninety degree phase shift is desired, the I driver 220 would be set to provide zero volts to mixer 216 so there is no signal at output 204, and the Q driver would be set to provide one volt to mixer 218 to produce a ninety degree phase shifted value at the

output 202. To produce a 45 degree phase shift, the I driver 220 is set to provide 0.707 volts and the Q driver is set to provide 0.707 volts so by vector addition, the signal at the output 202 is shifted 45 degrees from the signal at the input 210.

Fig. 15 illustrates the relationship between the I and Q signals applied to the mixers 216, 218, respectively. The relationship is a sine/cosine relationship. Appropriate I and Q values may be determined for any other desired degree phase shift (i.e., 0 - 360 degrees). For example, if a 45 degree phase shift is desired (i.e., Φ equals 45 degrees), I is at 0.707 (i.e., cosine Φ) while Q is at 0.707 (i.e., sine Φ) as determined within storage device 228. Such cosine and sine values are provided to the respective I and Q drivers 220, 222.

Referring again to Fig. 14, the signals outputted from mixers 216, 218 may be referred to as scaled quadrature cosine and sine components, respectively. The scaled quadrature component from mixer 216 may be indicated as $(\text{Cos}(\Phi)\text{Cos}(\varpi t))$ and the scaled quadrature component from mixer 218 may be indicated as $(\text{Sin}(\Phi)\text{Sin}(\varpi t))$.

The scaled quadrature components are applied to second power divider 208. Power divider 208 is configured to combine the first scaled quadrature component received from mixer 216 with the second scaled quadrature component received from mixer 218 to shift the phase angle of the local continuous wave signal by the phase shift angle received from phase adjuster 121.

In general, the phase of the signal passing within phase shifter 106 may be represented as $I + Q$ where $I = \text{Cos}(\Phi)\text{Cos}(\varpi t)$ and $Q = \text{Sin}(\Phi)\text{Sin}(\varpi t)$. Power divider 208 is configured to add the scaled first and second quadrature components received from mixers 216, 218 to implement phase shifting operations providing the adjusted continuous wave signal at output 202. The adjusted continuous wave signal having a phase angle shifted by the desired phase shift angle Φ is outputted from phase shifter 106 and may be applied via output 202 to power divider 107 and coupler 109.

As previously described, coupler 109 is configured to sum the adjusted continuous wave signal and the received modulated continuous wave signal. Such reduces the amplitude of the modulated continuous wave signal at the frequency of the continuous wave to reduce bleed through of the carrier signal.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

CLAIMS:

1.   A phase shifter comprising:

a first power divider configured to receive a signal and provide plural quadrature components of the signal;

plural mixers coupled with the first power divider and configured to scale the quadrature components using a phase shift angle; and

a second power divider coupled with the mixers and configured to combine the scaled quadrature components to shift the phase angle of the input signal by the phase shift angle.

2.   The phase shifter according to claim 1 wherein the first power divider comprises a ninety degree power divider configured to provide the signal into a sine component and a cosine component.

3.   The phase shifter according to claim 1 further comprising a storage device configured to store plural sine values and plural cosine values and to output a sine value and a cosine value individually corresponding to the phase shift angle.

4.   The phase shifter according to claim 1 further comprising a storage device configured to store a sine value and a cosine value individually corresponding to the phase shift angle.

5. The phase shifter according to claim 4 wherein the mixers are coupled with the storage device and individually configured to multiply one of the quadrature components by one of the sine value and the cosine value.

6. The phase shifter according to claim 1 wherein the second power divider comprises a zero degree power divider configured to add the scaled quadrature components.

7. A phase shifter comprising:

a first input configured to receive a signal having a phase angle;

a second input configured to receive a phase shift angle;

a first power divider coupled with the first input and configured to provide the signal into a first component and a second component;

a first mixer coupled with the first power divider and the second input and configured to scale the first component using the phase shift angle;

a second mixer coupled with the first power divider and the second input and configured to scale the second component using the phase shift angle; and

a second power divider coupled with the first mixer and the second mixer and configured to combine the first scaled component and the second scaled component to shift the phase angle of the input signal by the phase shift angle.

8. The phase shifter according to claim 7 wherein the first power divider comprises a ninety degree power divider configured to provide the signal into quadrature components.

9. The phase shifter according to claim 7 wherein the first power divider is configured to provide the signal into a sine component and a cosine component.

10. The phase shifter according to claim 7 further comprising a storage device coupled with the second input and being configured to store plural sine values and plural cosine values and output a sine value and a cosine value individually corresponding to the phase shift angle.

11. The phase shifter according to claim 7 further comprising a storage device configured to store a sine value and a cosine value individually corresponding to the phase shift angle.

12. The phase shifter according to claim 11 wherein the mixers are coupled with the storage device and individually configured to multiply one of the first and second components by one of the sine value and the cosine value.

13. The phase shifter according to claim 7 wherein the second power divider comprises a zero degree power divider configured to add the first scaled component and the second scaled component.

14. An interrogator of a backscatter communication system comprising:

a transmitter configured to output a local continuous wave signal and a radio frequency continuous wave signal; and

a receiver configured to receive the local continuous wave signal and a modulated radio frequency continuous wave signal, the receiver including:

a phase shifter configured to adjust a phase angle of the local continuous wave signal by a phase shift angle, the phase shifter including a first power divider configured to provide a first component and a second component of the local continuous wave signal, plural mixers configured to scale the first component and the second component using the phase shift angle, and a second power divider configured to combine the scaled first component and the scaled second component to provide an adjusted continuous wave signal; and

a coupler configured to combine the adjusted continuous wave signal and the modulated radio frequency continuous wave signal.

15.   The interrogator according to claim 14 wherein the first power divider is configured to provide the signal into quadrature components.

16.   The interrogator according to claim 14 wherein the first power divider comprises a ninety degree power divider configured to provide the signal into a sine component and a cosine component.

17.   The interrogator according to claim 14 further comprising a storage device configured to store plural sine values and plural cosine values and output a sine value and a cosine value individually corresponding to the phase shift angle.

18.   The interrogator according to claim 14 further comprising a storage device configured to store a sine value and a cosine value individually corresponding to the phase shift angle.

19.   The interrogator according to claim 18 wherein the mixers are coupled with the storage device and individually configured to multiply one of the first and second components by one of the sine value and the cosine value.

20.   The interrogator according to claim 14 wherein the second power divider comprises a zero degree power divider configured to add the scaled first component and the scaled second component.

21.   A phase shifter comprising:

a first input configured to receive a signal having a phase angle;

a second input configured to receive a phase shift angle;

a storage device configured to receive the phase shift angle, to store plural sine values and plural cosine values, and to output the sine value and cosine value which correspond to the phase shift angle;

a ninety degree power divider coupled with the first input and configured to provide the signal into a sine component and a cosine component;

a first mixer coupled with the ninety degree power divider and the storage device and configured to multiply the sine component of the signal by the sine value corresponding to the phase shift angle;

a second mixer coupled with the ninety degree power divider and the storage device and configured to multiply the cosine component of the signal by the cosine value corresponding to the phase shift angle; and

a zero degree power divider coupled with the first mixer and the second mixer and configured to add the sine component of the signal and the cosine component of the signal to shift the phase angle of the signal by the phase shift angle.

22. A method of shifting a phase angle of a signal comprising:

providing a signal having a phase angle;

providing a phase shift angle;

providing the signal into a first component and a second component;

scaling the first component using the phase shift angle;

scaling the second component using the phase shift angle;

combining the first component and the second component after the scalings to shift the phase angle of the signal by the phase shift angle.

23. The method according to claim 22 wherein the providing the signal into a first component and a second component comprises providing the signal into quadrature components.

24. The method according to claim 22 wherein the providing the signal into a first component and a second component comprises providing the signal into a sine component and a cosine component.

25. The method according to claim 22 further comprising:

storing a plurality of sine values and cosine values; and

outputting one sine value and one cosine value individually corresponding to the phase shift angle.

26. The method according to claim 22 further comprising storing a sine value and a cosine value individually corresponding to the phase shift angle.

27. The method according to claim 26 wherein the scalings individually comprise multiplying one of the first component and the second component by one of the sine value and the cosine value.

28. The method according to claim 22 wherein the combining comprises adding the scaled first component and the scaled second component.

29. A method of shifting the phase angle of a signal comprising:

providing a signal having a phase angle;

providing a phase shift angle;

providing the signal into a sine component and a cosine component;

multiplying the sine component by a sine value corresponding to the phase shift angle;

multiplying the cosine component by a cosine value corresponding to the phase shift angle; and

adding the sine component and the cosine component after the multiplyings to shift the phase angle of the signal by the phase shift angle.

30. The method according to claim 29 further comprising storing a plurality of sine values and cosine values and outputting a sine value and a cosine value individually corresponding to the phase shift angle.

31. The method according to claim 29 wherein the providing the signal into a sine component and a cosine component comprises providing using a ninety degree power divider.

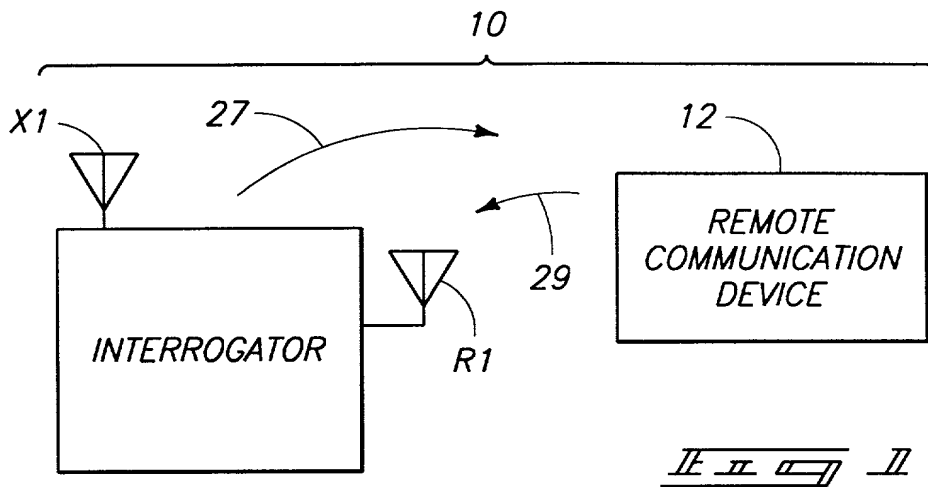32. The method according to claim 29 wherein the multiplyings individually comprise multiplying using a mixer.

33. The method according to claim 29 wherein the combining comprises adding the scaled first component and the scaled second component.

34. The method according to claim 29 wherein the adding comprises adding using a zero degree power divider.

35. A method of operating a coherent interrogator of a backscatter communication system comprising:

outputting a radio frequency continuous wave signal;

providing a local continuous wave signal;

receiving a modulated continuous wave signal;

providing a phase shift angle;

adjusting the phase of the local continuous wave signal using the phase shift angle to provide an adjusted continuous wave signal, the adjusting including:

providing the local continuous wave signal into a first component and a second component;

scaling the first component using the phase shift angle;

scaling the second component using the phase shift angle; and

combining the first component and the second component after the scalings to shift the phase angle of the local continuous wave signal by the phase shift angle; and

combining the adjusted continuous wave signal and the modulated continuous wave signal.

36. The method according to claim 35 wherein the providing the signal into a first component and a second component comprises providing the signal into quadrature components.

37.   The method according to claim 35 wherein the providing the signal into a first component and a second component comprises providing the signal into a sine component and a cosine component.

38.   The method according to claim 35 further comprising storing a plurality of sine values and cosine values and outputting a sine value and a cosine value individually corresponding to the phase shift angle.

39.   The method according to claim 35 further comprising storing a sine value and a cosine value individually corresponding to the phase shift angle.

40.   The method according to claim 39 wherein the scalings individually comprise multiplying one of the first component and the second component by one of the sine value and the cosine value.

41.   The method according to claim 35 wherein the combining comprises adding the scaled first component and the scaled second component.
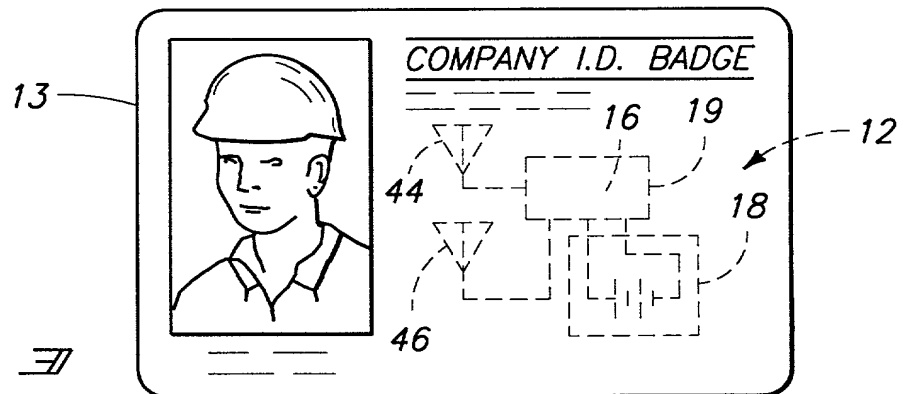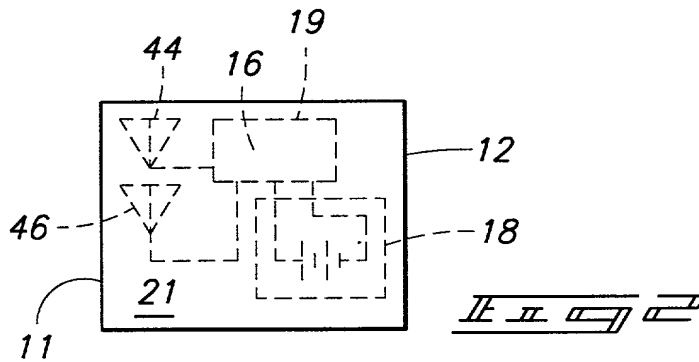
ABSTRACT OF THE DISCLOSURE

The present invention includes phase shifters, interrogators, methods of shifting a phase angle of a signal, and methods of operating an interrogator. One aspect of the present invention provides a phase shifter including a first power divider configured to receive a signal and provide plural quadrature components of the signal; plural mixers coupled with the first power divider and configured to scale the quadrature components using a phase shift angle; and a second power divider coupled with the mixers and configured to combine the scaled quadrature components to shift the phase angle of the input signal by the phase shift angle.

FIG. 1
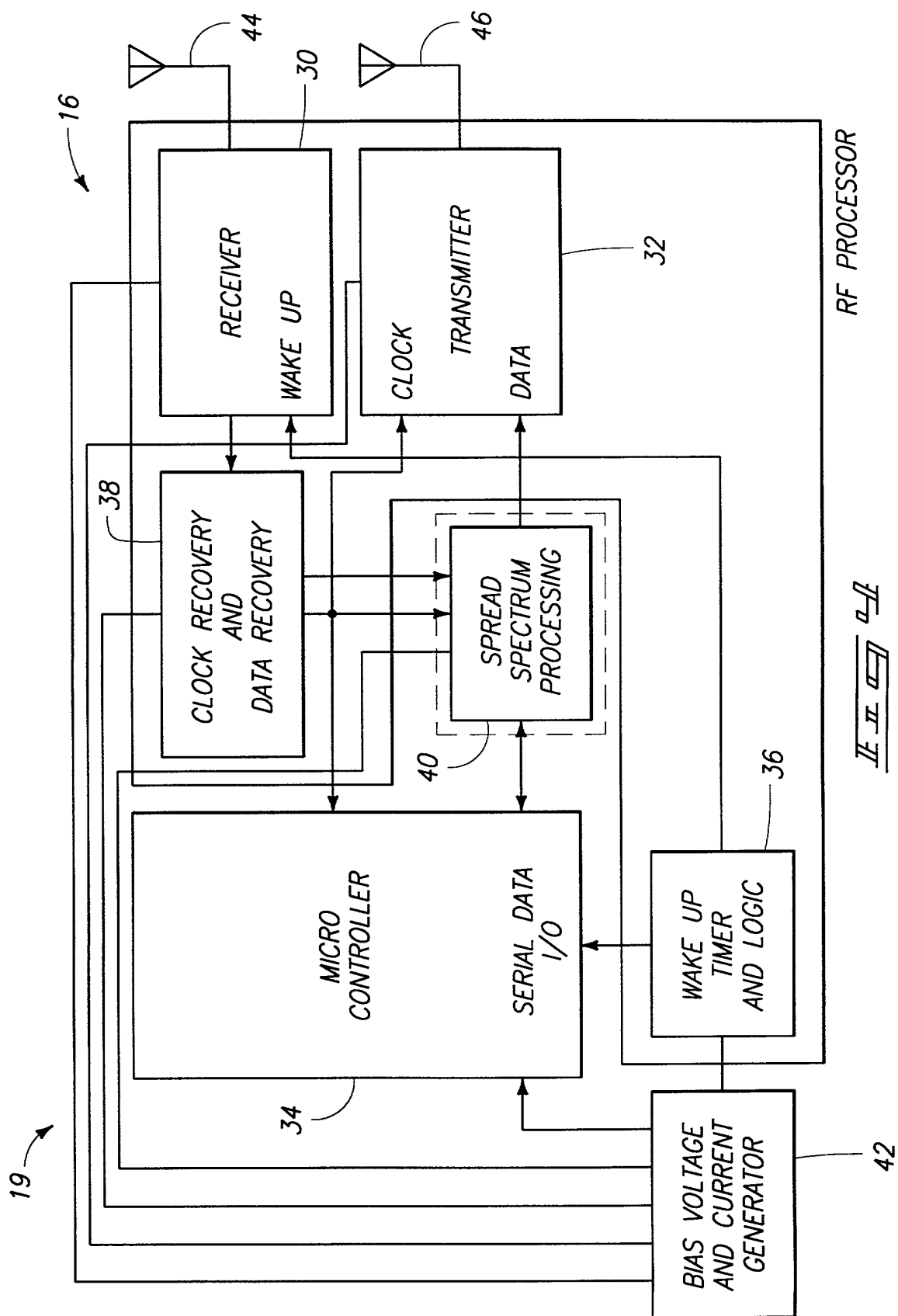

FIG. 2

FIG. 3

MI40−177

FIG 4

RF PROCESSOR

X1

R1

26

74

RF
SECTION

85

I

Q

82

A/D

84

A/D

FPGA

72

FIG. 5

70

MICROCONTROLLER

76

RAM

78

EPROM

80

FLASH
MEMORY

FIG. 6

FIG. 7

FIG. 8

VARIABLE ATTENUATOR — 105

CONTROL

110

POWER DIVIDER — 107

108

COUPLER — 114

115

FIG. 9

AMPLITUDE (dBm)

PHASE (Degrees)

FIG. 10

FREQUENCY

FIG. 11

FREQUENCY

FIG. 12

FORWARD	CALIBRATION PERIOD	PREAMBLE	DATA

FIG. 13

10/10

PHASE ADJUSTER — 203 / 121

POWER DIVIDER — 107

STORAGE DEVICE — 228

D/A CONVERTER — 224

D/A CONVERTER — 226

PHASE SHIFTED SIGNAL OUT
$Cos(\emptyset)Cos(wt)+Sin(\emptyset)Sin(wt)$ — 202

201

I DRIVER — 220

Q DRIVER — 222

$Cos(\emptyset)Cos(wt)$ — 204

$Sin(\emptyset)Sin(wt)$ — 206

SECOND POWER DIVIDER — 208

FIRST POWER DIVIDER — 200

216 — $Cos(wt)$ — 212

214 — $Sin(wt)$ — 218

VARIABLE ATTENUATOR — 105
$Cos(wt)$ — 210

106

FIG 14

FIG 15
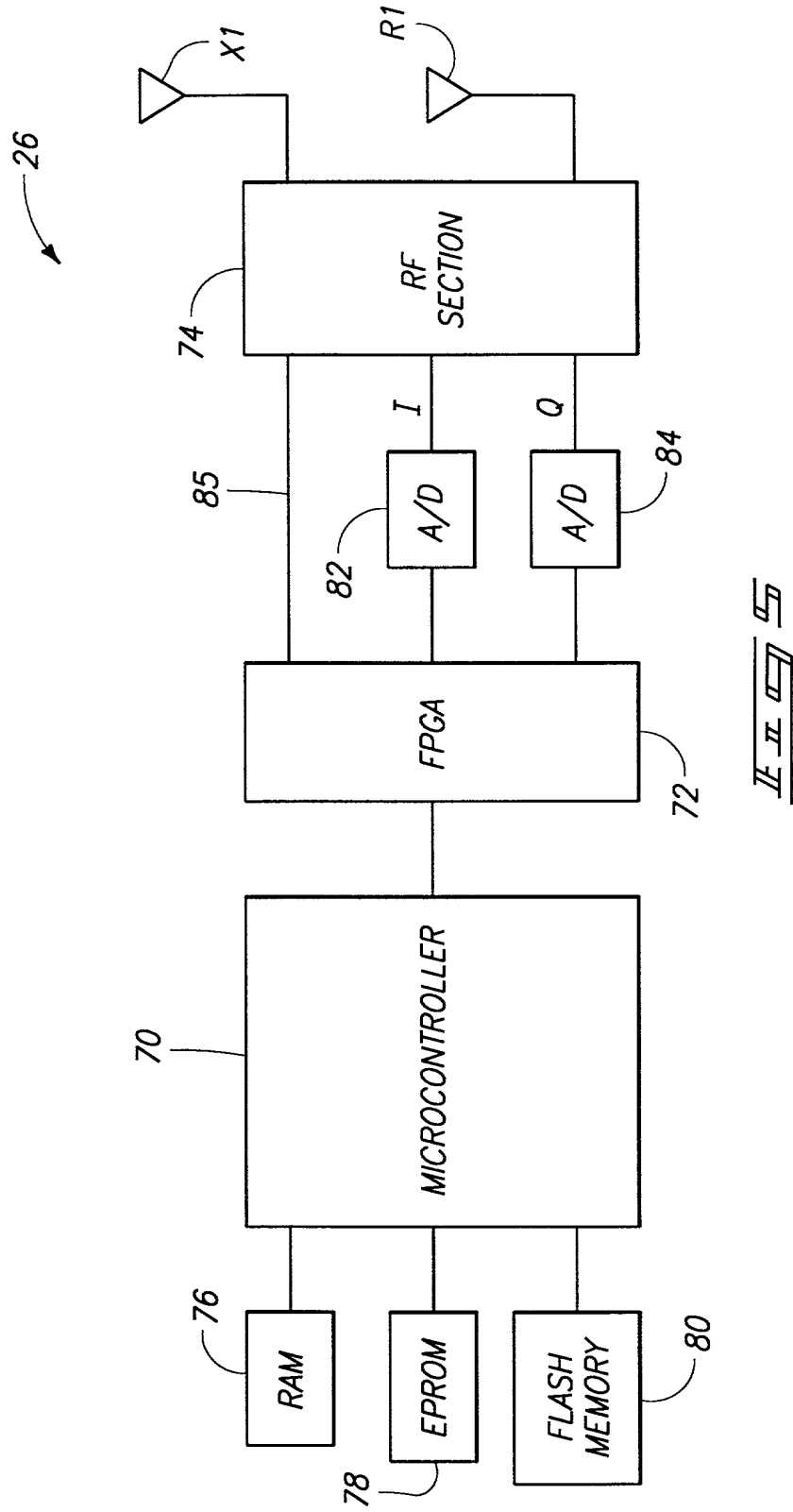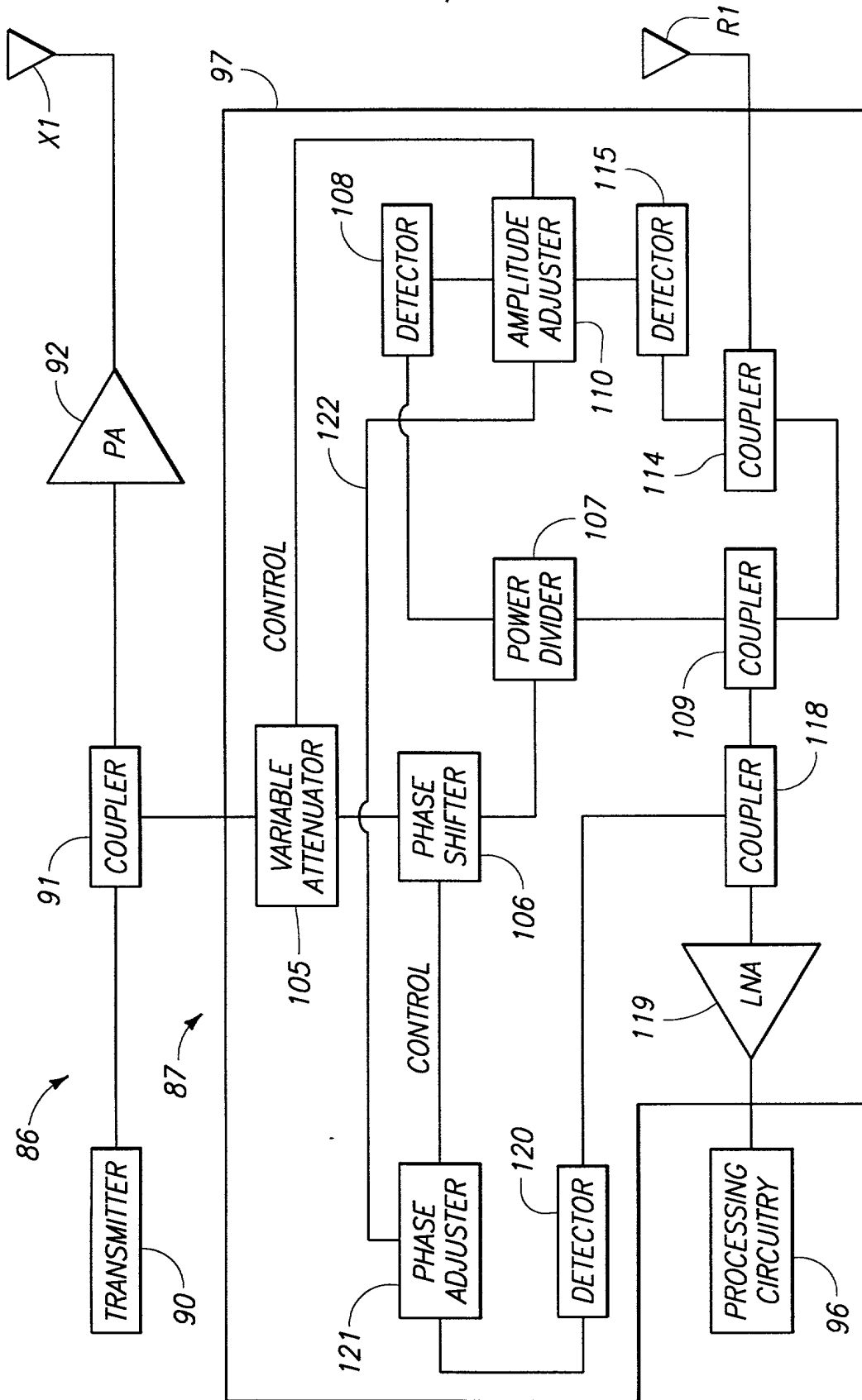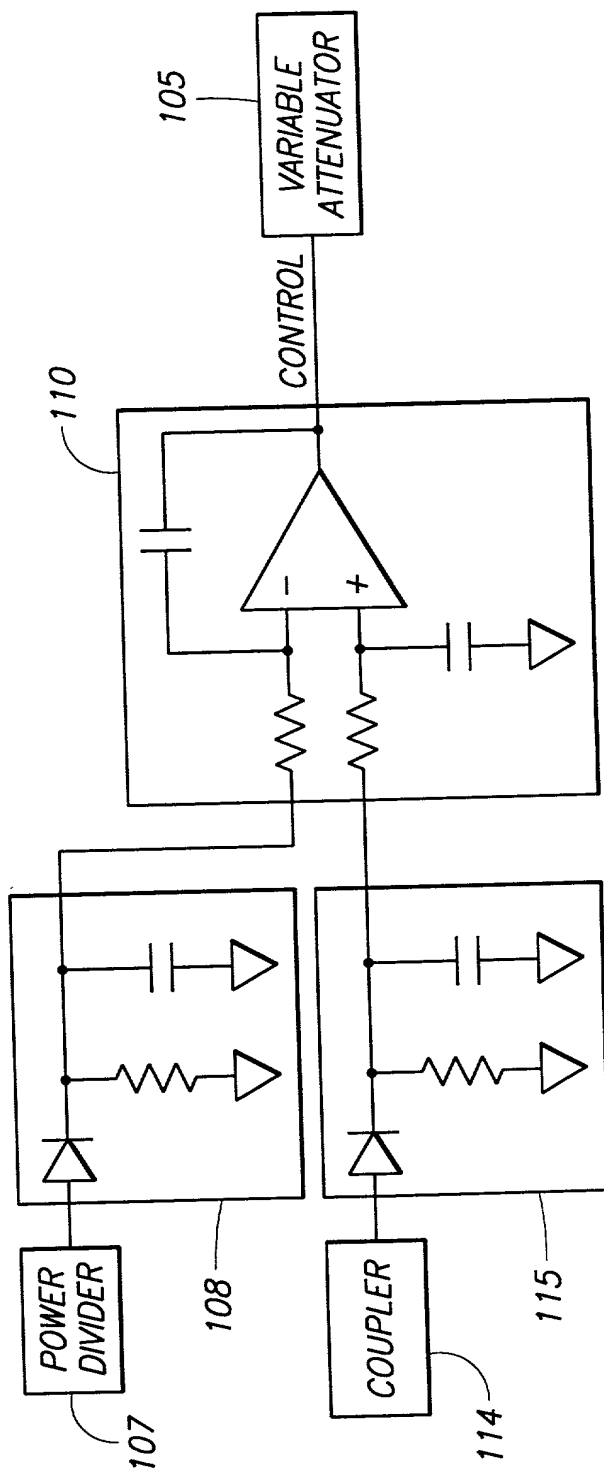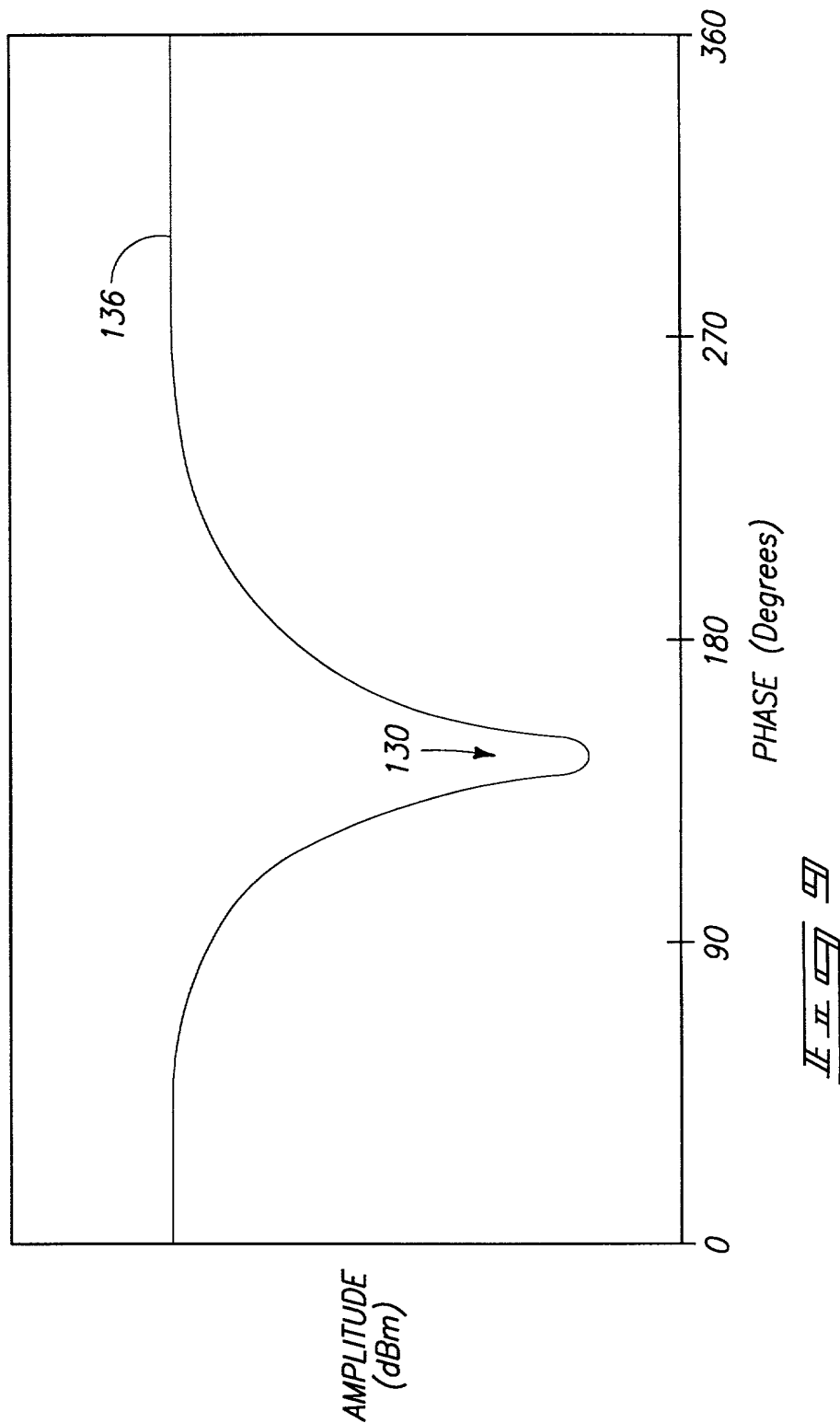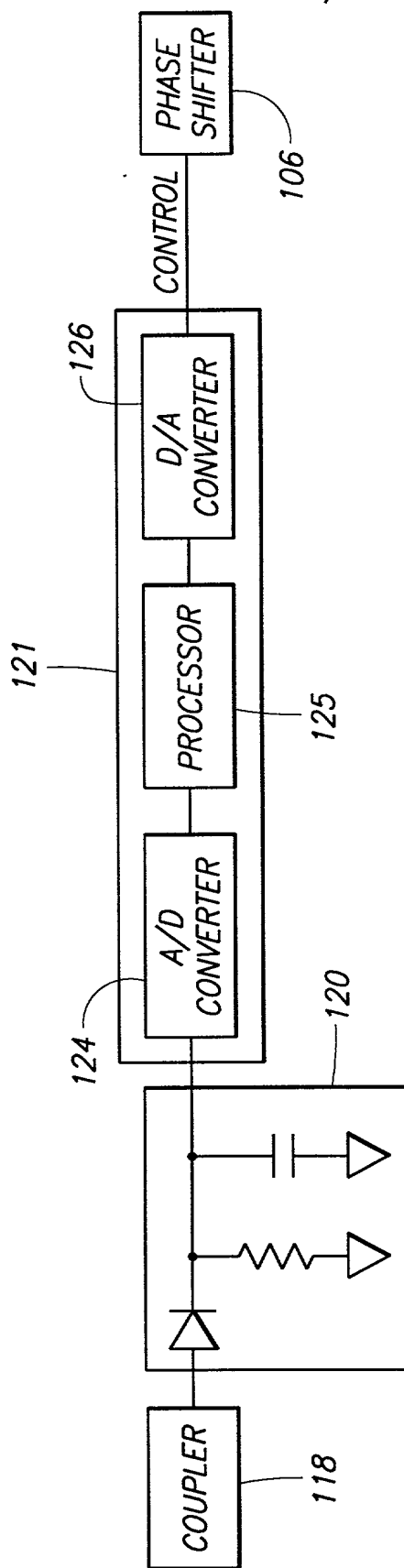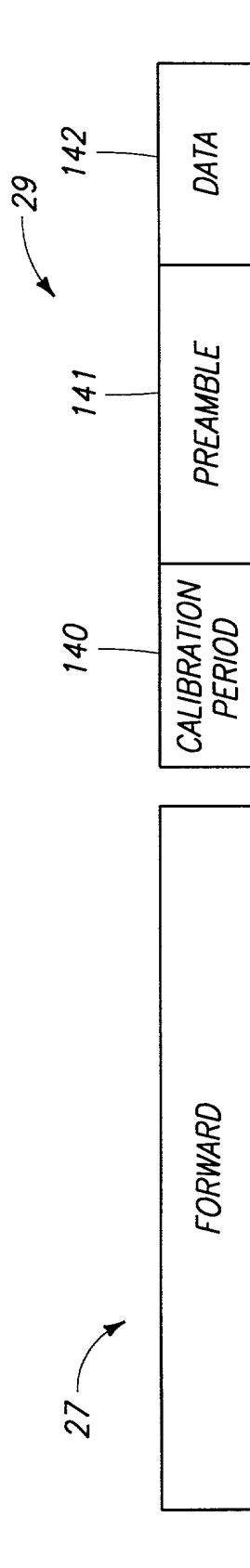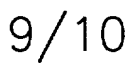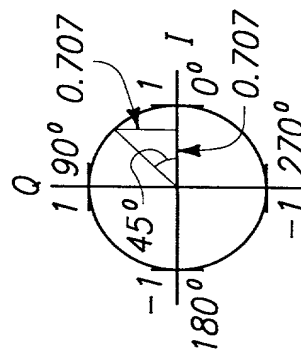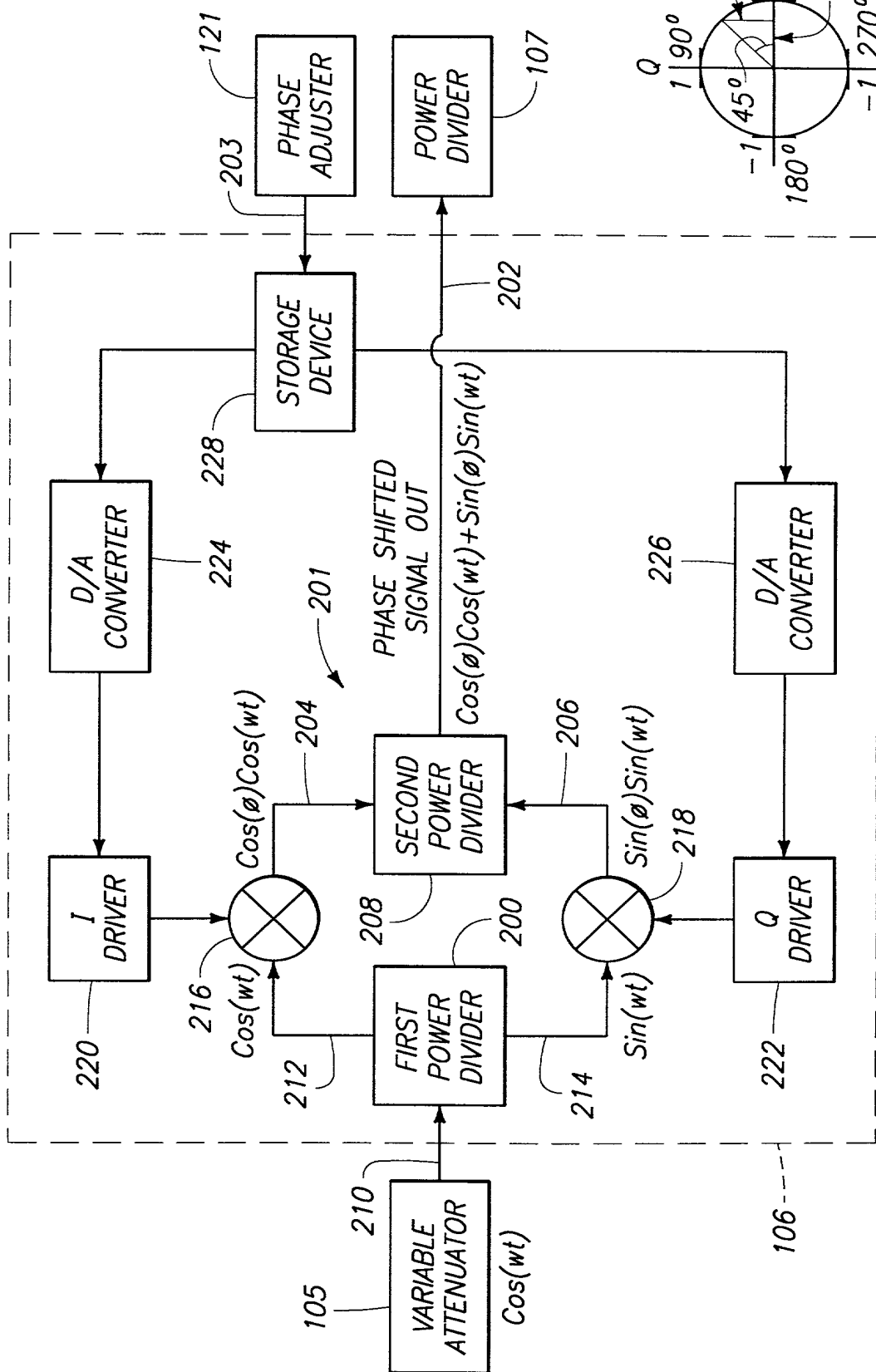
I
Q
0°
90° 0.707
1
0.707
45°
180°
270°
1
−1
−1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application Serial No. . . . . Unknown
Filing Date . . . . Filed herewith
Inventor . . . . Roy Greeff et al.
Assignee . . . . Micron Communications, Inc.
Group Art Unit . . . . Unknown
Examiner . . . . Unknown
Attorney's Docket No. MI40-177
Title: Phase Shifters, Interrogators, Methods of Shifting a Phase Angle of a Signal,
and Methods of Operating an Interrogator

POWER OF ATTORNEY BY ASSIGNEE AND
CERTIFICATE BY ASSIGNEE UNDER 37 CFR §3.73(b)

To: Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

MICRON COMMUNICATIONS, INC., the Assignee of the entire

right, title and interest in the above-identified patent application by

assignment attached hereto, hereby appoints the attorneys and agents of

the firm of WELLS, ST. JOHN, ROBERTS, GREGORY & MATKIN

P.S., listed as follows:

Richard J. St. John	Reg. No. 19,363
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Randy A. Gregory	Reg. No. 30,386
Mark S. Matkin	Reg. No. 32,268
James L. Price	Reg. No. 27,376
Deepak Malhotra	Reg. No. 33,560
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Lance R. Sadler	Reg. No. 38,605
James D. Shaurette	Reg. No. 39,833

and also attorneys Michael L. Lynch (Reg. No. 30,871) and Lia Pappas Dennison (Reg. No. 34,095) of Micron Communications, Inc., as its attorneys with full power of substitution to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

The Assignee certifies that the above-identified Assignment has been reviewed and to the best of Assignee's knowledge and belief, title is in the Assignee.
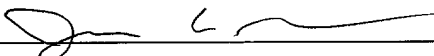
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MICRON COMMUNICATIONS, INC.

Dated: 3/2/99   By: _____
                            Name: James E. O'Toole
                            Title: Chairman and President

DECLARATION OF JOINT INVENTORS FOR PATENT APPLICATION

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled: Phase Shifters, Interrogators, Methods of Shifting a Phase Angle of a Signal, and Methods of operating an Interrogator, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56.

PRIOR FOREIGN APPLICATIONS:

I hereby state that no applications for foreign patents or inventor's certificates have been filed prior to the date of execution of this declaration.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful
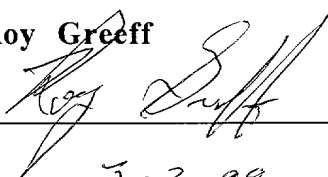
false statement may jeopardize the validity of the application or any

patent issued therefrom.

* * * * * * * * *

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Inventor's Signature: _____

Date: _____3-2-99_____

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